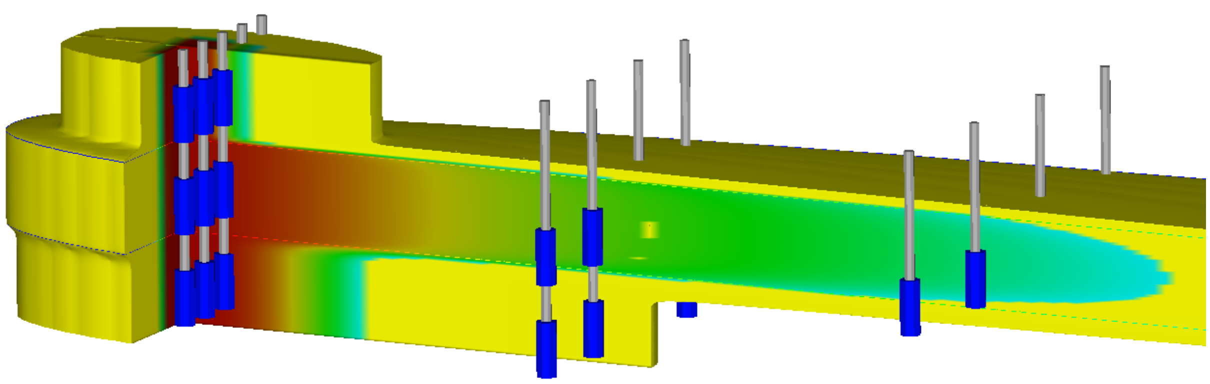
Modeling LNAPL Depletion at a Former Xylene Processing Facility (Germany)

by Grant R. Carey, Ph.D.

Porewater Solutions

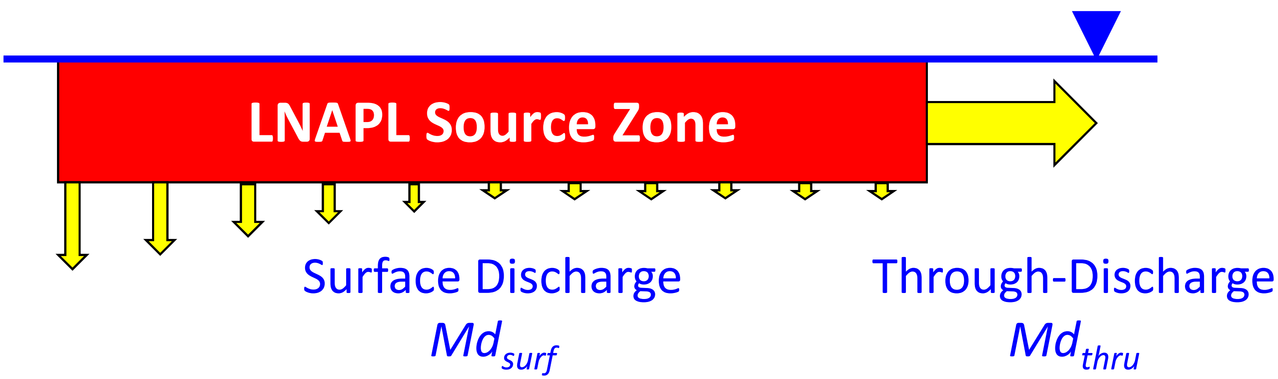
Ottawa, Ontario, Canada

www.porewater.com gcarey@porewater.com



Porewater Solutions
Expertise • Experience • Innovation

LNAPL Depletion Modeling



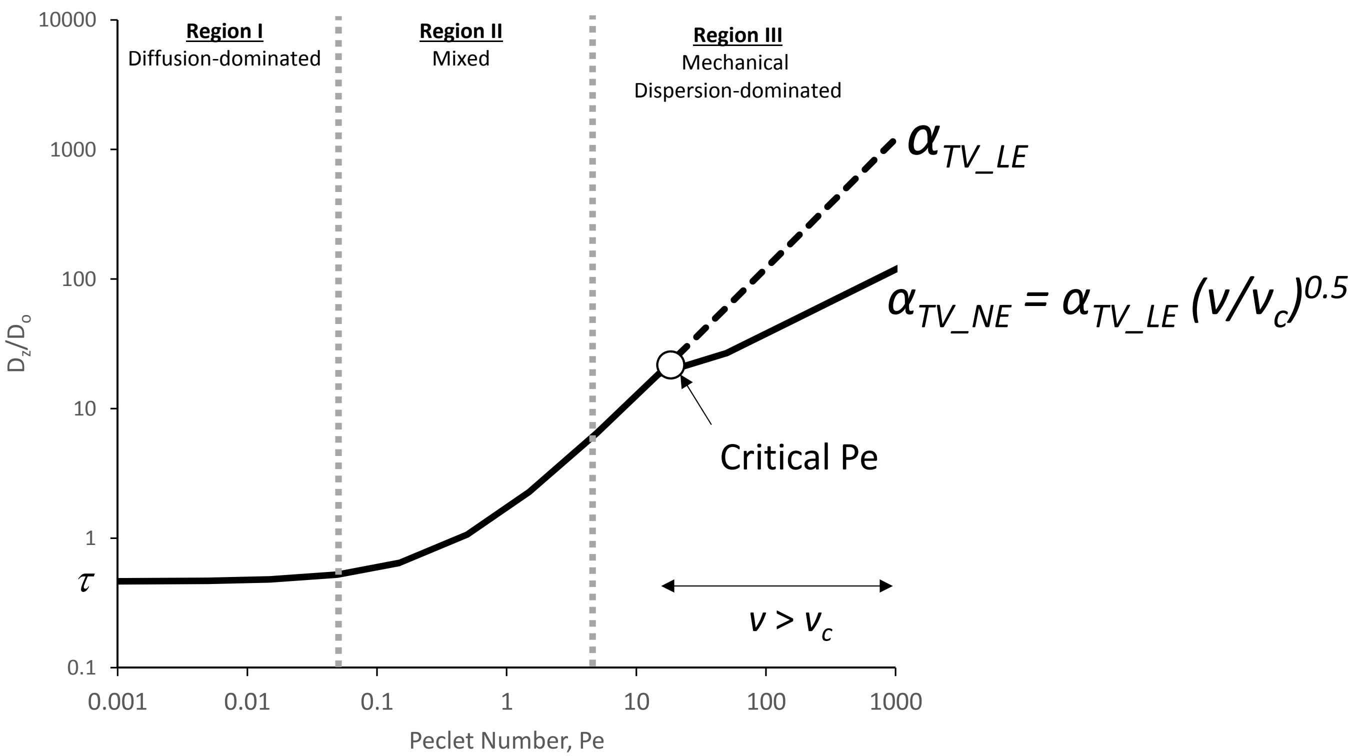
- **Screening Model Uses**
  - Compare Timeframes
  - Refine CSM
  - Identify data gaps
  - Regulatory support
- **Critical field properties**
  - LNAPL thickness
  - Transverse dispersivity
- **Case study example**

Schafer and Therrien (1995)
Former Xylene Processing Facility

Porewater Solutions
Expertise • Experience • Innovation

Transverse Vertical Dispersivity

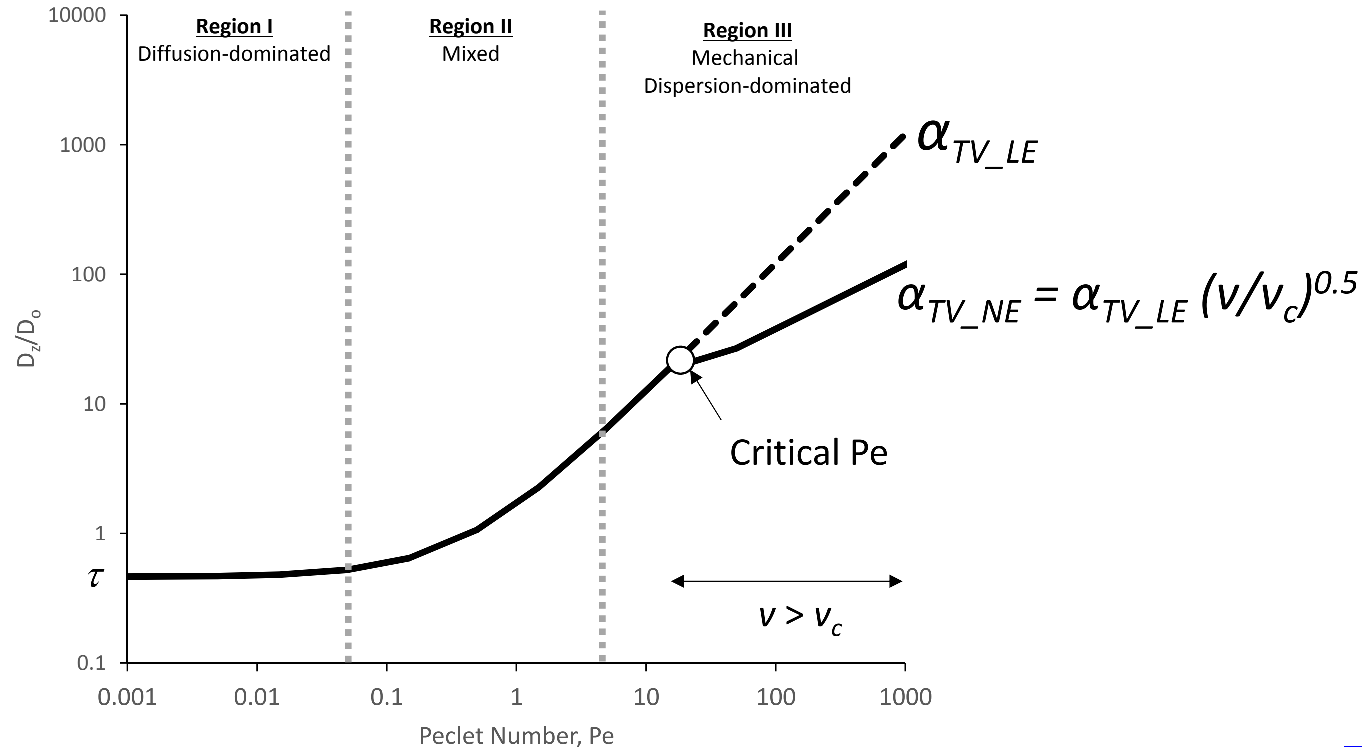
Klenk and Grathwohl (2002), and Carey et al. (2015)



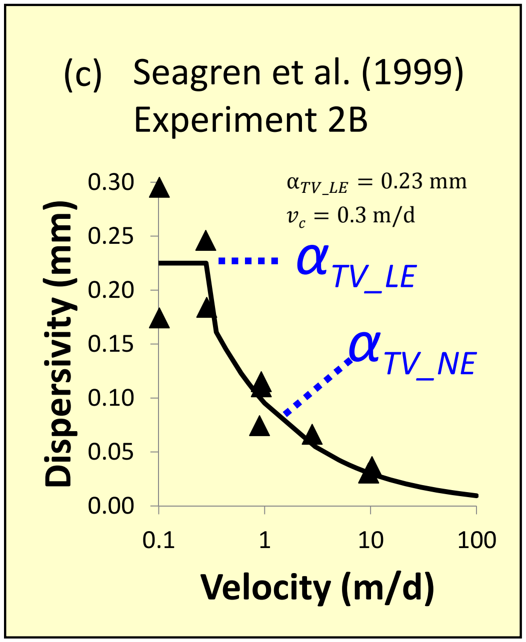
Porewater Solutions
Expertise • Experience • Innovation

Transverse Vertical Dispersivity

Klenk and Grathwohl (2002), and Carey et al. (2015)



Carey et al. (2015a)

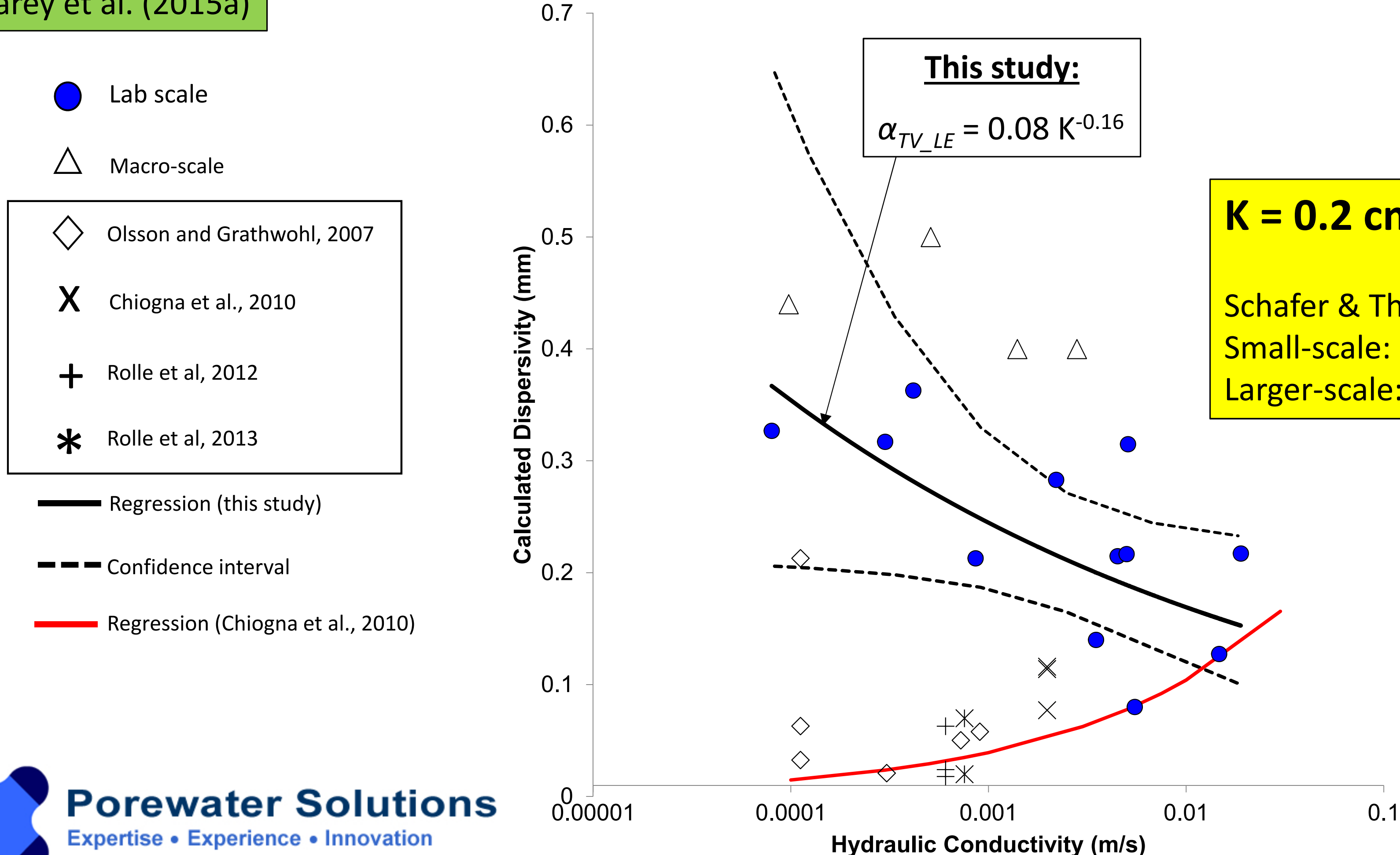


v_c ~ 3 to 5 m/d for pool dissolution

Porewater Solutions
Expertise • Experience • Innovation

Transverse Vertical Dispersivity (LE) vs. K

Carey et al. (2015a)

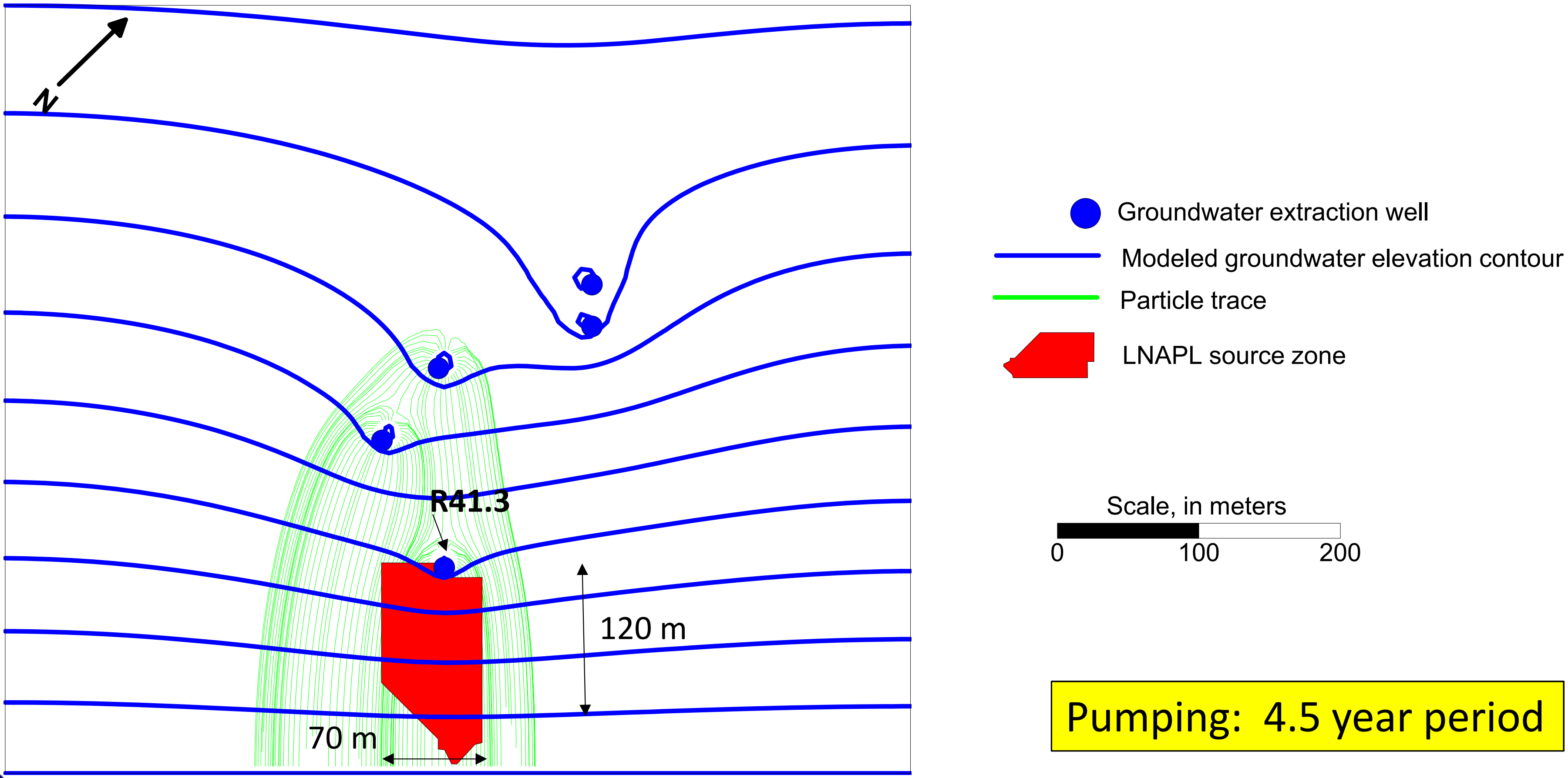


K = 0.2 cm/s

Schafer & Therrien: α_{TV_LE} = 10 mm
Small-scale: α_{TV_LE} = 0.22 mm
Larger-scale: α_{TV_LE} = 0.4 mm

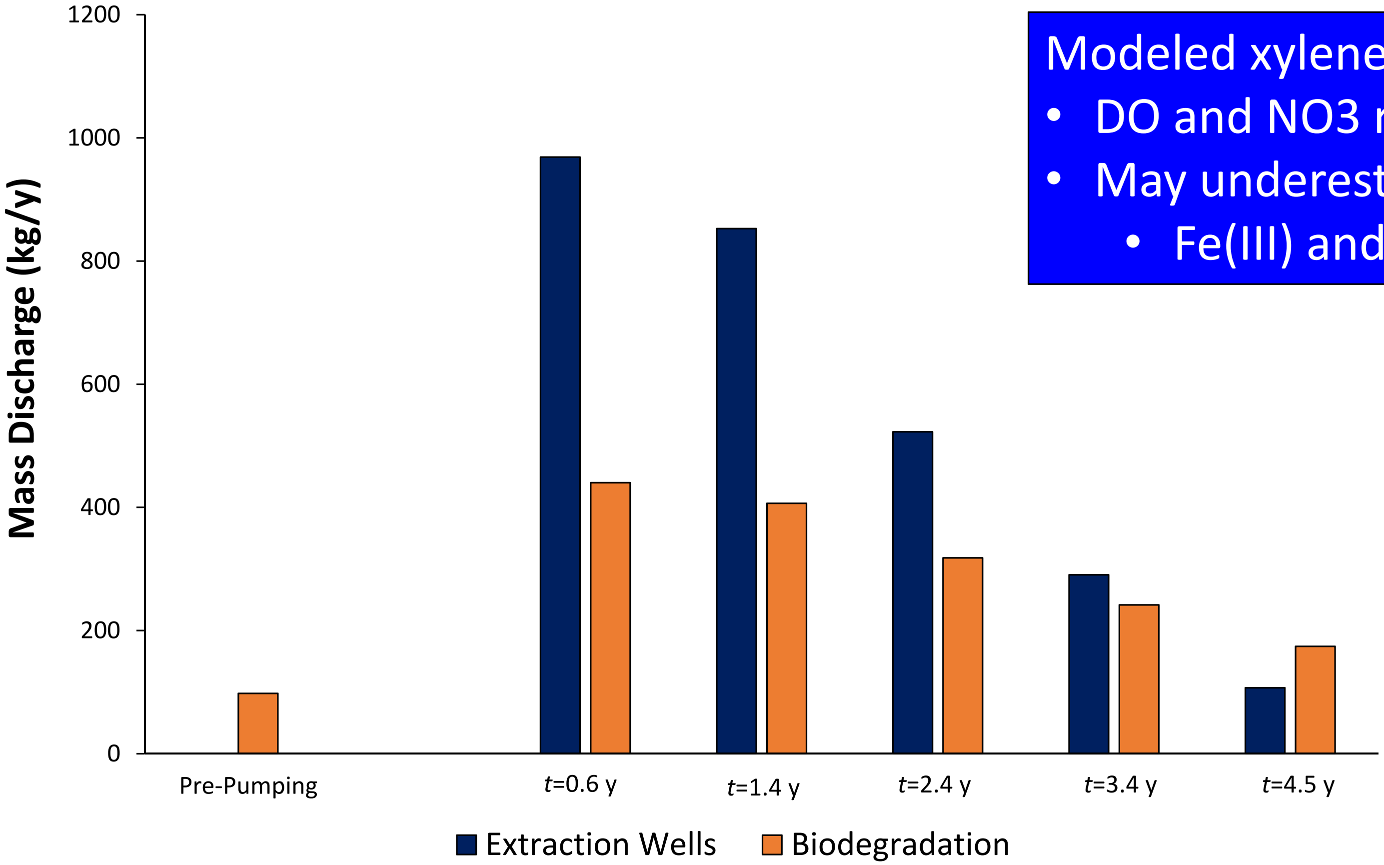
Porewater Solutions
Expertise • Experience • Innovation

Former Xylene Processing Facility (Germany)



Pumping: 4.5 year period

Estimated Mass Discharge Based on Schafer and Therrien (1995)



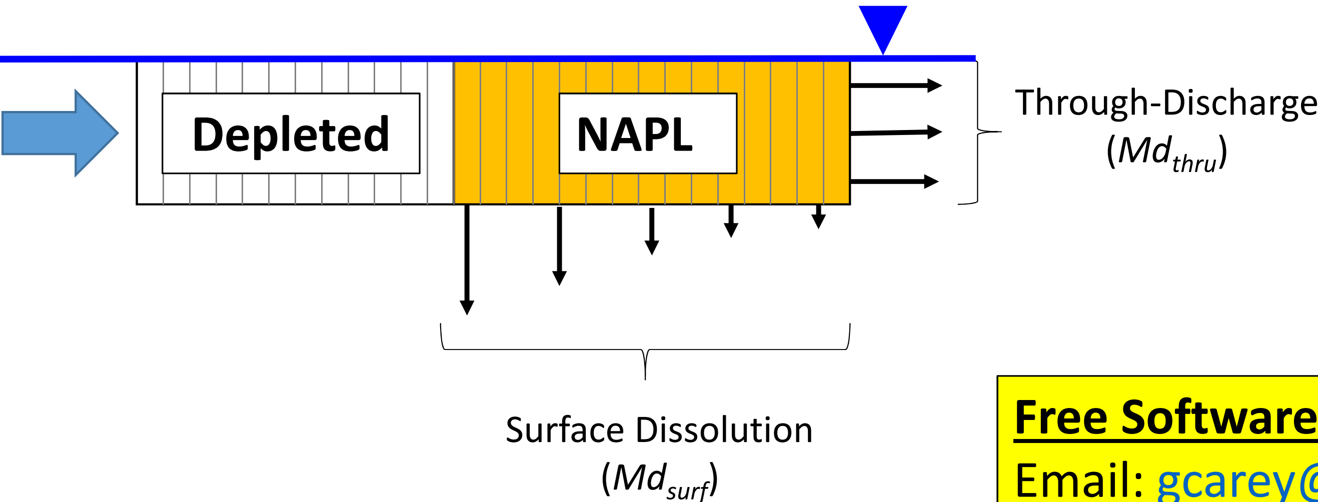
Modeled xylene biodegradation

- DO and NO3 reduction only
- May underestimate actual by 2x
  - Fe(III) and SO4 reduction

Porewater Solutions
Expertise • Experience • Innovation

NAPL Depletion Model (NDM): Mass Discharge

Carey et al. (2014a)

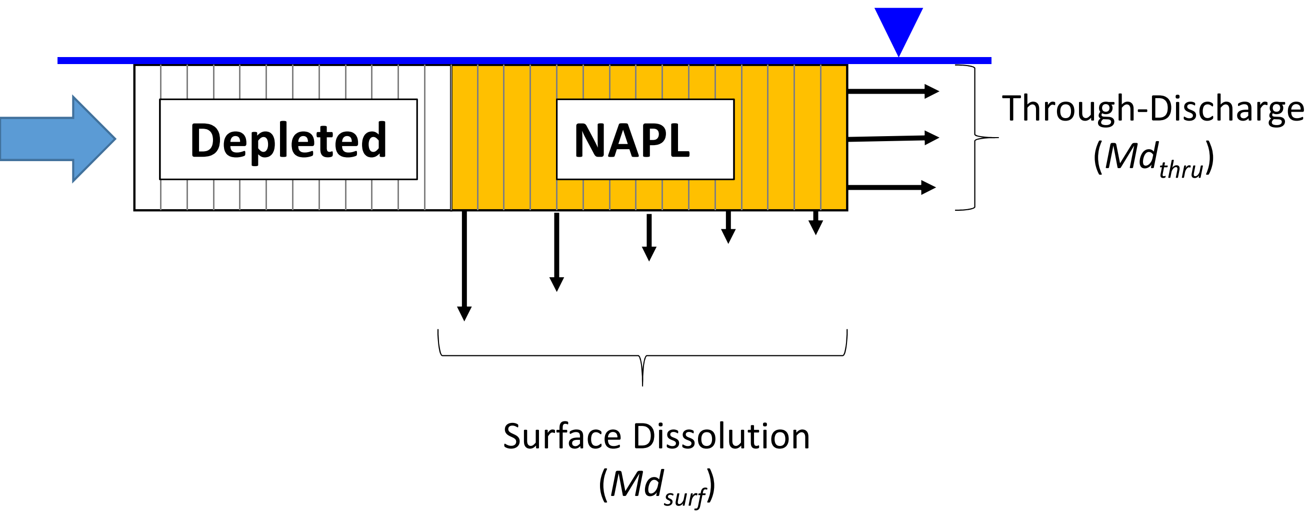


Free Software:
Email: gcarey@porewater.com
Download after Sep. 30th: www.porewater.com

Porewater Solutions
Expertise • Experience • Innovation

NAPL Depletion Model (NDM): Mass Discharge

Carey et al. (2014a)

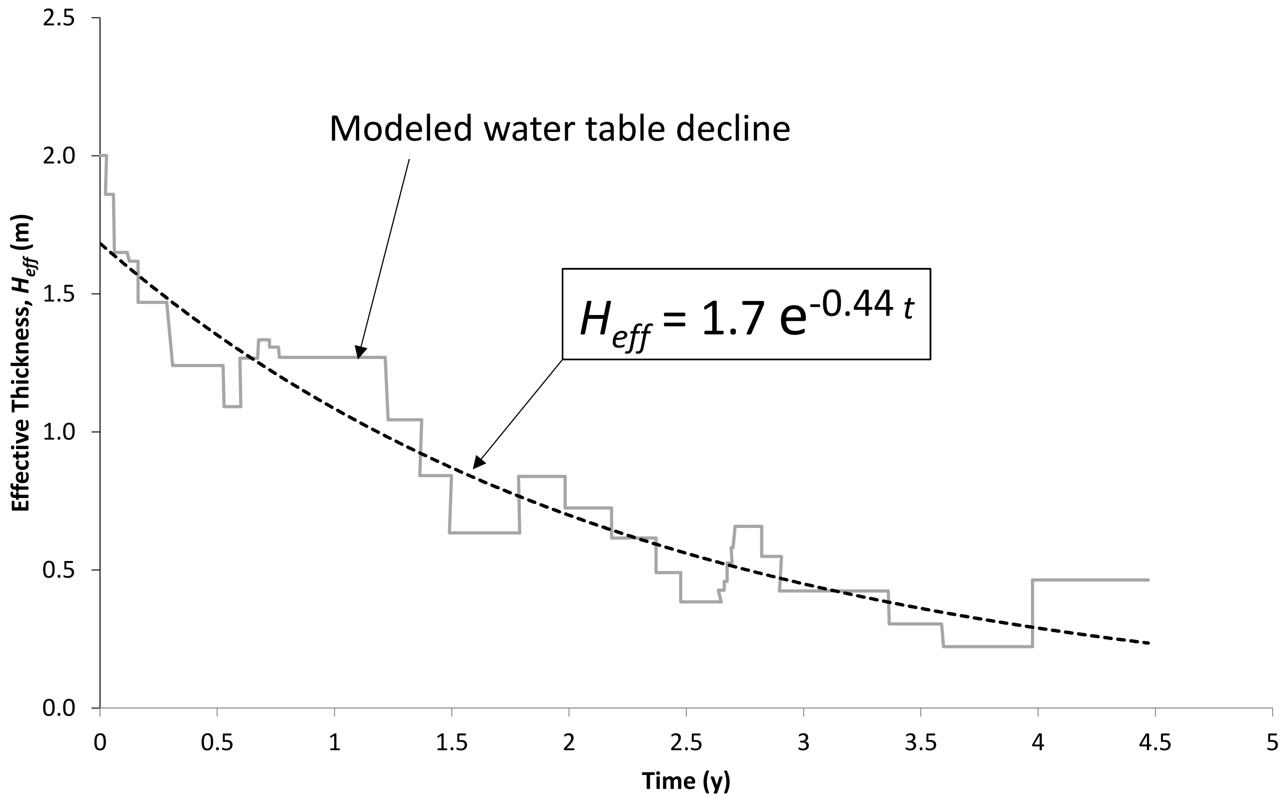


Empirical Relationship (K in m/s)	
$\tau = 0.60\ K^{0.030}$	(i)
$\theta_t = 0.30\ K^{-0.026}$	(ii)
$\theta_e = 0.41\ K^{0.064}$, $K \leq 1\text{x}10^{-2}$ m/s	(iii)
$\theta_e = (0.29\ K^{-0.026}) - 0.03$, $K > 1\text{x}10^{-2}$ m/s	(iv)
$\alpha_{TV} = 0.08\ K^{-0.16}$, $v \leq v_c$	(v)
$\alpha_{TV\_NE} = 0.08\ K^{-0.16}\ (v_c/v)^{0.5}$, $v > v_c$	(vi)
$\alpha_{aw} = 0.112\ (100\ K)^{0.211}$	(vii)
$n = 13.14\ (100\ K)^{0.246}$ $K \geq 1\text{x}10\text{-}4$ m/s	(viii)
$S_{wr} = 0.015\ (100\ K)^{-0.218}$	(ix)

Carey et al. (2015a,b,c)

Porewater Solutions
Expertise • Experience • Innovation

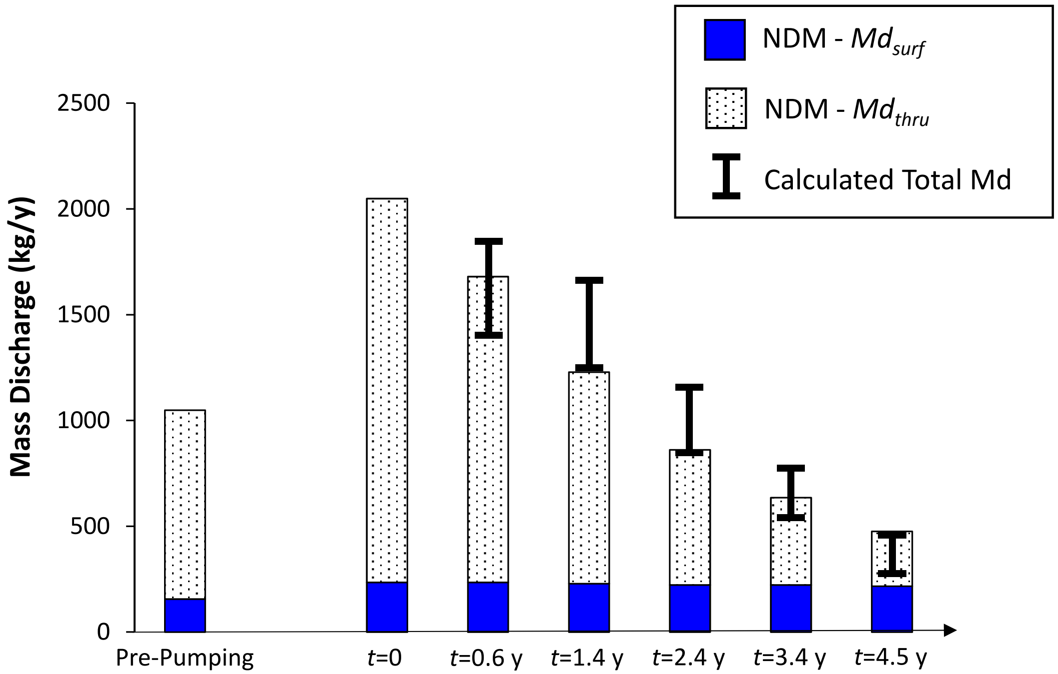
Saturated Source Zone Thickness vs. Time



Note: Effective thickness of the LNAPL source zone was determined based on an assumed source zone bottom elevation of 19.75 m, and the fluctuating water table elevation. t=0 corresponds to May 1, 1988.

Porewater Solutions
Expertise • Experience • Innovation

Modeled and Estimated Mass Discharge



Notes:

1. *Groundwater extraction system started at t=0.*
2. *Md = mass discharge.*
3. *Range in calculated total Md is based on the potential difference between including and excluding xylene biodegradation under manganogenesis, ferrogenesis, and sulfate reduction.*

Porewater Solutions
Expertise • Experience • Innovation

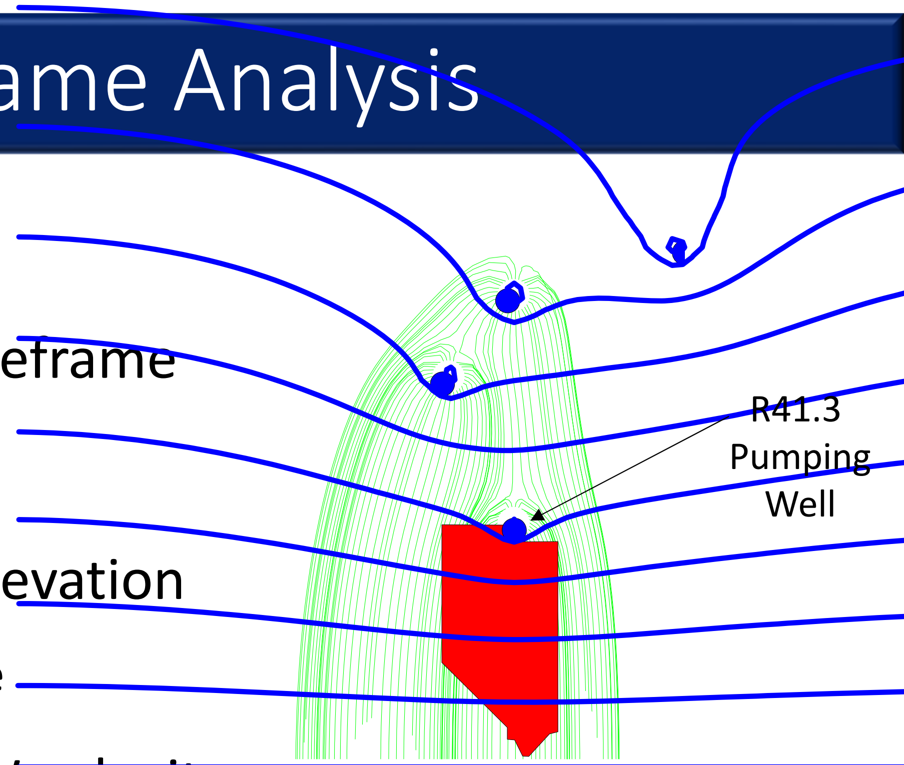
Remediation Timeframe Analysis

Goal

- Evaluate influence of Q on depletion timeframe

Approach

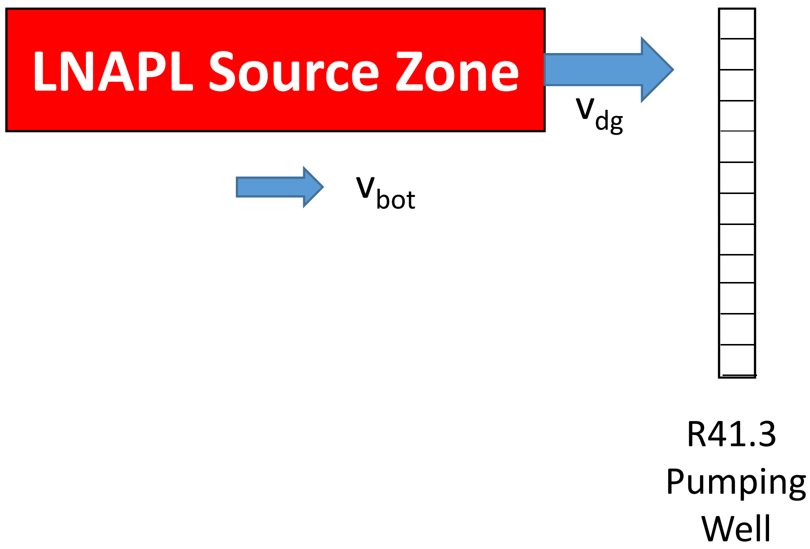
- Assume constant, average water table elevation
  - Source zone 0.85 m thick below water table
- Evaluate influence of increasing Q on GW velocity
- Model LNAPL depletion for each scenario

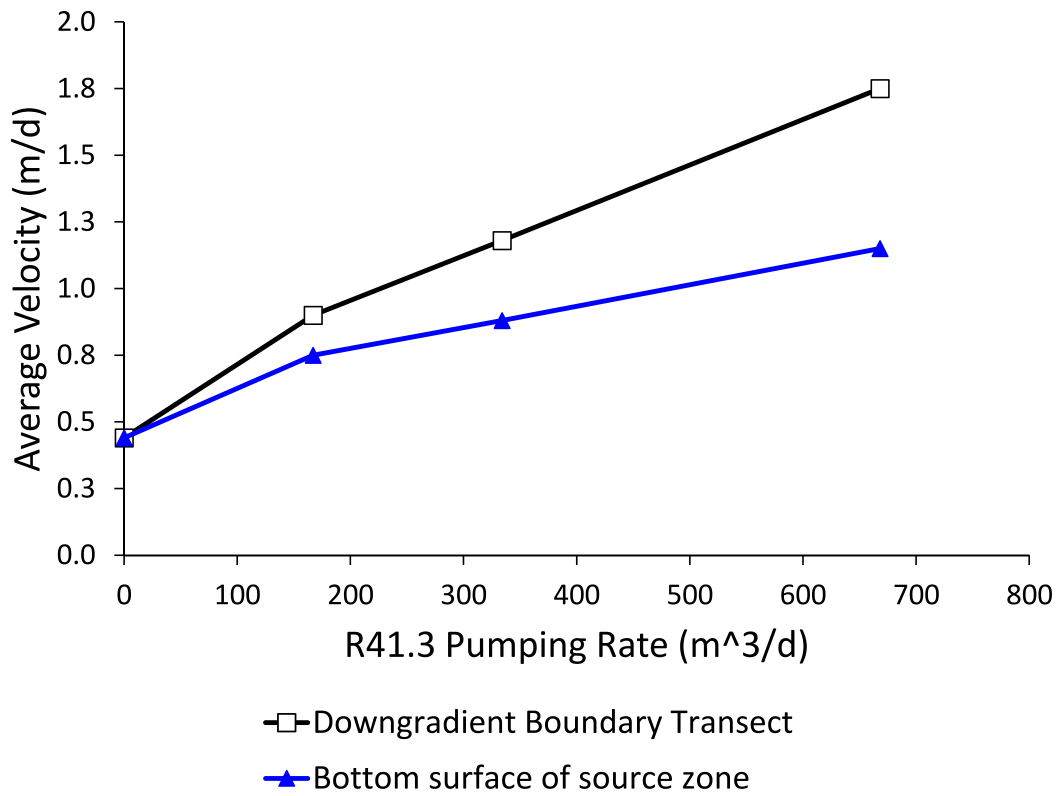


Scenarios
Q=0 (MNA)
Qx1 (system design)
R41.3 Qx2
R41.3 Qx4

Porewater Solutions
Expertise • Experience • Innovation

Velocity vs. Pumping Rate

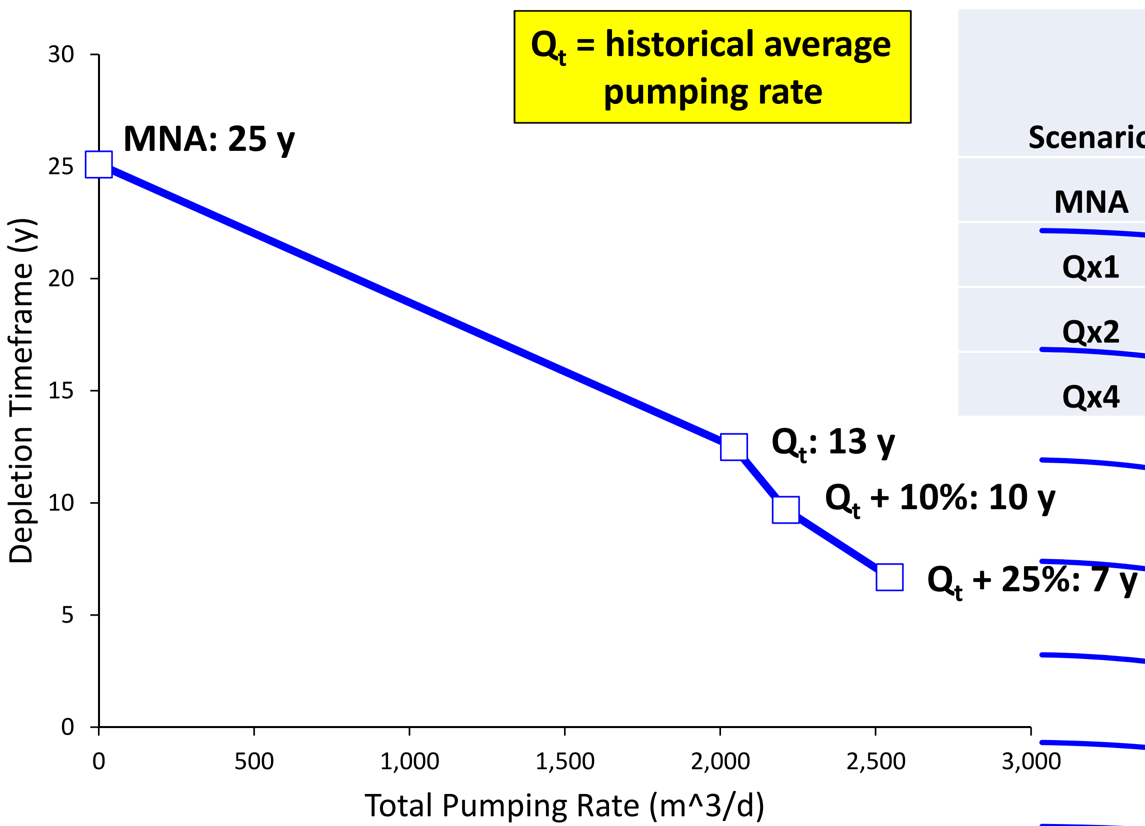




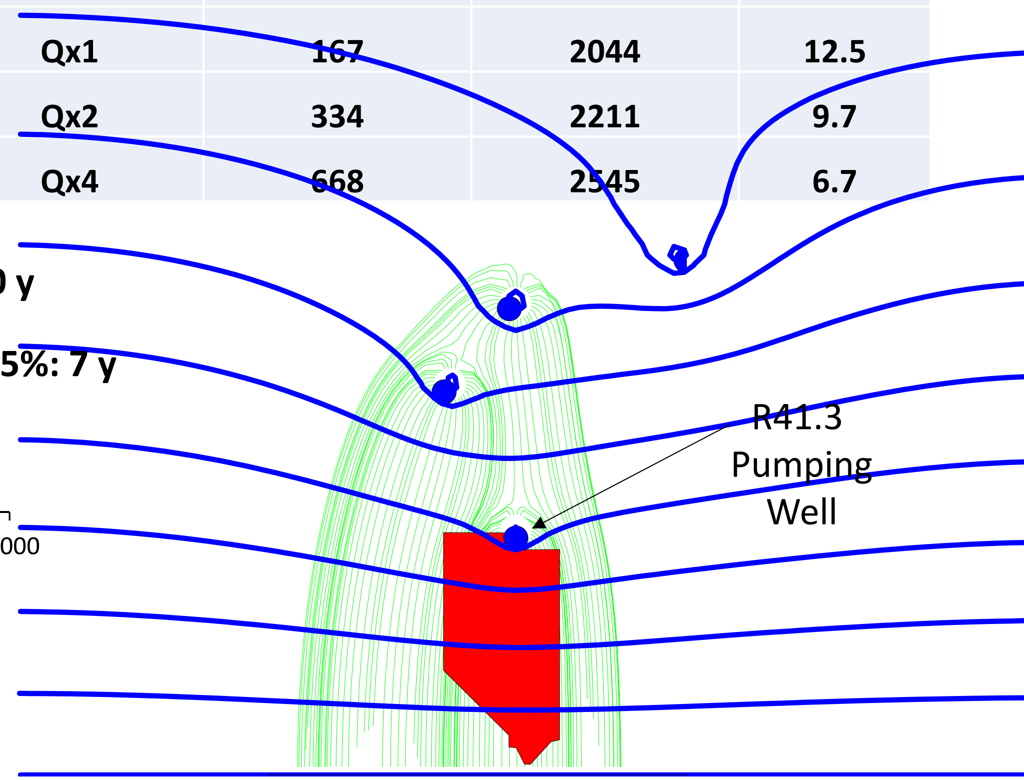
Porewater Solutions
Expertise • Experience • Innovation

Note: Pumping rates at extraction wells R41.2, R41.4, R41.6, and R41.8 were simulated to be constant for all scenarios where the R41.3 well pumping rate was greater than zero.

Depletion Timeframe vs. Total Pumping Rate



Scenario	R41.3 Pumping Rate (m^3/d)	Combined Pumping Rate (m^3/d)	Remediation Timeframe (y)
MNA	0	0	25.1
Qx1	167	2044	12.5
Qx2	334	2211	9.7
Qx4	668	2545	6.7



Porewater Solutions
Expertise • Experience • Innovation

Summary

- Transverse dispersivity based on K
- Model matched estimated mass discharge vs. time
  - Without any input calibration
- MNA may be appropriate if no receptors at risk
- Increased pumping rate at R41.3
  - Small incremental cost
  - Large reduction in remediation timeframe

Porewater Solutions
Expertise • Experience • Innovation

Questions

Grant Carey, Ph.D.
Porewater Solutions

613-270-9458
gcarey@porewater.com
www.porewater.com

Porewater Solutions
Expertise • Experience • Innovation